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MICROPLASTICS

The impact of microplastics on marine pollution and human health

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ABSTRACT

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Microplastics are small plastic particles of less than 5 mm, and the environmental problems of the accumulation are increasing, which is a serious social problem. Microplastics enter the ocean and act as endocrine disruptors in marine organisms, disrupting the ecological system, and eventually endangering humanity, the end of the food chain. At the present time when social issues on microplastics are increasing, there is a need to properly recognise these problems and seek solutions. This thesis work discusses the current state of microplastics, their impact on the marine ecosystem and human body, and the trends of policy and research for microplastic detection and removal.

Key words
Human health, Marine environment, Marine pollution, Microplastics

CONCEPT DEFINITIONS AND ABBREVIATIONS

List of Definition

Nanoplastics: One kind of microplastics, less than 1 micromillimeter

Neonicotinoids: Nicotine-based neuro-stimulatory insecticide

Microbeads: Solid processed plastic particles with diameter 5 mm or less

List of abbreviation

PS: Polystyrene

PE: Polyethylene

PVC: Polyvinyl chloride

PET: Polyethylene terephthalate

PES: polyester

PP: polypropylene

PB: poly-1-butene

EDS: Energy-dispersive X-ray spectroscopy

SEM: Scanning electron microscopy

Pys-GC/MS: Pyrolysis-gas chromatography mass spectrometry

HIS: Hyperspectral imaging system

FT-IR: Fourier transform infrared

ATR: Attenuated total reflection

DSC: Differential scanning calorimeter

TGA: Thermogravimetric analysis

SEM-EDS: Scanning electron microscopy with energy-dispersive X-ray spectroscopy

ABSTRACT
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1 INTRODUCTION

Plastic has been used for various purposes in human daily life because of its high strength, light weight and low cost. As the technology for producing plastics derived from petroleum has advanced, the recycling of used plastics has decreased (Barnes, Galgani, Thompson & Barlaz 2009). Plastic waste is increasing rapidly in land and aquatic environments, with the increasing amount of plastic being disposed of as garbage. (He, Chen, Shao, Zhang & Lü 2019.)

Consumption of plastics is increasing rapidly every year, as well as global plastics production in 2012 was 280 million tons, an increase of 170 times over the past 60 years, and the current trend is expected to reach 33 billion tons by 2050 with (IEA 2018). In the last 65 years from 1950 to 2015, the cumulative production of plastics was 8,300 million tons, of which only 7 % (600 million tons) of plastics were recycled, with about 60 % of 4,900 million tons of plastic being disposed of as waste. Among 7% of waste was incinerated, the rest of it was landfilled or dumped. (Geyer, Jambeck & Law 2017.) In 2017, plastic waste released the ocean from 4.8 million to 12.7 million tons, accounting for 60-80% of the total marine solid pollutants. At this rate, it is predicted that by 2050 there will be more plastic in the ocean than fish.

Marine ecosystems are threatened by marine waste and are becoming a serious source of pollution. Among the marine waste, plastics account for 60 to 80 % of the waste that flows into the sea as usage has soared over the last few decades. As such, plastic waste is a major source of threats to marine ecosystems along with climate change and indiscriminate overfishing.

Jambeck (2005) estimated plastic waste flowed to the sea in 2010 from at least 4.8 million tons to up to 12.7 million tons and analyzed that if no solutions were taken to deal with marine waste, four times the current volume would flow into the ocean by 2025 (Jambeck, Geyer, Wilcox, Siegler, Perryman, Andrady, Narayan & Law 2015). In addition, each square mile of ocean is occupied by 46,000 pieces of plastic, and at least 10,000 seabirds and 100,000 sharks, turtles and dolphins die every year eating plastic (Korea Environment Preservation Corporation, 2014).

Of all the plastic waste, microplastic is a bigger problem. Microplastic means plastic with a length or diameter of less than 5mm (Barboza & Gimenez 2015). It can reduce the health and productivity of marine ecosystems because it is so fine that it is difficult to collect and it can be mistaken and eaten by marine organisms, causing human damage through the consumption of fish (Jovanović 2017).

Plastic pollution is a global problem that continues to threaten human health and the environment. Until now, the management of plastic waste has focused mainly on large size plastic materials. Plastic containers discharged from domestic households are collected and used for recycling, but most of them are large plastic products visible to the naked eye. However, poorly collected plastics have been exposed to the environment for a long time and are decomposed into many microplastics by photolysis by ultraviolet light or by physical stimulus (Andrady 2017). The problem of environmental pollution caused by such small broken microplastics is socially increased seriously. In addition, microplastics from personal hygiene products, cosmetics, and tire wear are causing more serious environmental pollution (Obbard, Sadri, Wong, Khitun, Baker & Tompson 2014). Microplastics, along with the flow of wind and sewage, pollute far-away seas, causing serious environmental risks (Korez, Gutow & Saborowski 2019) .

The aim of this research is to determine what is microplastic and how microplastics affect to marine ecosystems and human bodies eventually. Various methods for detecting microplastics and policies and research for removing microplastics in various countries will be discussed. Although the problem of microplastics is a problem around the world, since most microplastics research and regulations are being conducted mainly in developed countries, this report was written with information from countries with regulations on microplastics.

2 MICROPLASTICS

Microplastics are so small that they are dumped into the ocean without being filtered out of sewage treatment facilities, and marine organisms are misunderstood by marine organisms as food containing adsorbable or additive contaminants, causing marine ecological disturbances. As shown in FIGURE 1, microplastics are classified according to size. The smaller of microplastic, the easier to being intake. Ingestion of microplastics has been reported to cause physical injuries to marine organisms, changes in eating behavior, growth and decreased fertility. Microplastics can be consumed at all levels of nutrition through the food chain. In other words, fish and shellfish intake can eventually reach the human body. (Estahbanati & Fahrenfeld 2016.)

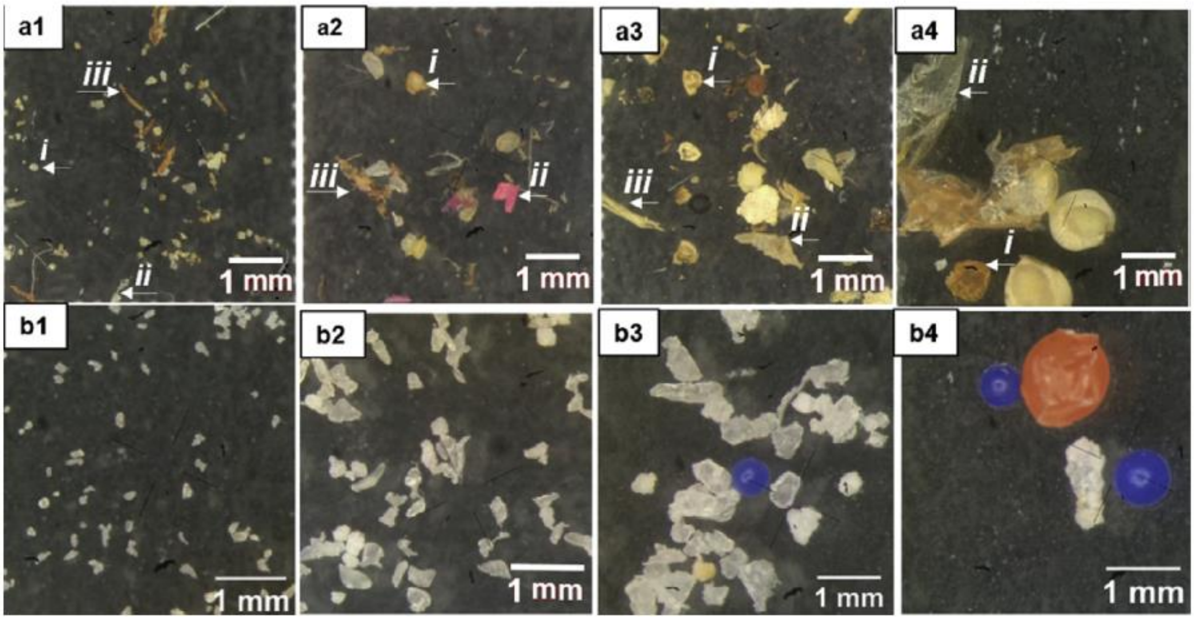

FIGURE 1. (A) Microplastics recovered in samples in the 1) 63e125 mm size category, 2) 125e250 mm size category, 3) 250e500 mm size category, and 4) 500e2000 mm size category. (B)Microplastics recovered from personal care products in the 1) 63e125 mm size category, 2) 125e250 mm size category, 3) 250e500 mm size category, and4) 500e2000 mm size category. Examples of different particles classifications are labeled i) primary microplastic, ii) secondary microplastic, and iii) non-microplastic particles excluded during the counting step. (Estahbanati & Fahrenfeld 2016)

2.1 Microplastics

Plastics can be carved into small pieces by environmental factors, and can be changed to numerous microplastics (Moore 2008). Microplastic means less than 5 mm of plastic and can be classified into primary microplastic and secondary microplastic according to the expected source. Primary microplastics are intentionally small plastics from the time of production, and have been used in cosmetics, industrial abrasives, toothpaste, cleaning products, detergents, whole body exfoliants, face washes, and toothpastes for decades. It also includes resin pellets, which are used as raw materials for the production of various kinds of plastic products. Secondary microplastics are larger in size when they are produced but are artificially or naturally micronized plastics during the subsequent use, consumption and disposal of plastics. Secondary microplastics can be generated not only by physical forces but also by photochemical processes such as light. (Greenpeace International 2018.)

2.1.1 Primary microplastics

Primary microplastics are plastics that are released directly into the environment in the form of small particulates. Primary microplastics are manufactured as microbeads, capsules, fibers or pellets. Examples include microbeads used in cosmetics and personal care products, industrial scrubbers used for abrasive blast cleaning, microfibers used in textiles, and virgin resin pellets used in plastic manufacturing processes. A plastic particle used as a raw material for household goods (drugs, detergents, cleansers) or emitted from tire wear, synthetic fiber laundry and so on. Each product can contain between 5,000 and 95,000 microplastics(Julien Boucher 2017).

2.1.2 Secondary microplastics

Large plastic (pat bottles, plastic bags, fishing nets) have been exposed to the marine environment and have been carved into small pieces. Secondary microplastics which are formed by larger plastic are decomposed. Ultraviolet rays, wind and wave action break plastic into millions of small pieces. A good example of a secondary microplastic is a piece of polystyrene (PS) that breaks to the fish and chip boxes at the beach. These chips of microplastics go straight to the sea if they are not properly disposed. (Greenpeace 2016.)

Karami and Golieskardi (2017) surveyed 17 salt brands in eight countries (Australia, France, Iran, Japan, Malaysia, New Zealand, Portugal, South Africa) and found microplastic with an average size of 515±171 μm, for every kilogram of salt except one brand. It was also analyzed that human intake 37 microplastic per year from the edible salt, which did not have a fatal effect on the human body, but it was concluded that accumulation of microplastics products from marine ecosystems could gradually increase and threaten human health. (Karami, Golieskardi, Choo, Larat, Galloway & Salamatinia 2017.) Microplastics can be classified according to size, such as Megaplastics, Macroplastics, Mesoplastics, Microplastics and Nanoplastics as shown in TABLE 1.

TABLE 1. Classification of microplastic (Miller, Kroon & Motti 2017)

Substance	Size (diameter)	Examples
Megaplastic	Over 1 m	Fishing gear, net, rope, hull etc.
Macroplastic	Over 25 mm, less than 1 m	Plastic bag, wrapping paper, fishing rod, buoy, balloon, etc.
Mesoplastic	Over 5 mm, less than 25 mm	Bottle cap, plastic piece, etc.
Microplastic	Less than 5 mm	Primary microplastic: Raw materials for household goods, tire wear, synthetic fiber laundry, etc. Secondary microplastic: Plastic that is fragmented by marine environment
Nanoplastic	Less than 1 micromillimeter	One kind of microplastic

2.2 Potential hazards of microplastics

Microplastics pose a risk to a variety of chemicals used in the manufacture and processing of plastics, including the risks of plastics themselves. When these substances are inhaled, ingested, and absorbed in vivo, they accumulate and concentrate in the body, which is expected to cause great problems not only for marine life and humans, but also for the global ecosystem. (Song, Hong, Eo, Jang, Han, Isobe & Shim 2018.) Currently, research on the amount, distribution and pollution of marine plastics in the world has been extensively conducted. As a result, studies on the toxicity of microplastic intake by marine organisms are being actively conducted. Along with this, researches for predicting the effect of microplastics on the human body have been actively conducted. Therefore, based on the physicochemical effects of microplastics on organisms on Earth, investigating the effects of microplastics on marine life is needed (Watts, Urbina, Goodhead, Moger, Lewis & Galloway 2016). Moreover, through the research using PS nanoplastics, the potential dangers of nanoplastics to the human body and recognize importance of research of nanoplastics will be searched.

2.2.1 Physicochemical effects of Microplastics on Ecosystems

The plastic that has become inseparable from human life has provided various benefits to the mankind. As shown in FIGURE 2, the chemical effect such as soil physico-chemistry, affecting terrestrial food webs, organism's growth reduction, triggering lethal toxicity, cytotoxicity increases as the physical effect as size of the microplastic decreases. They are naturally or artificially divided into different sizes, affecting natural ecosystems (Machado, Anderson Abel de Souza, Kloas, Zarfl, Hempel & Rillig 2018). Typically, polyvinyl alcohol (PVA) for crop cultivation or the mulching method of covering the soil surface with Polyethylene film improves crop yields due to physical properties that prevent the exchange of gases or compounds, leading to early cultivation. Not only did it make it possible, but it also improved the sweetness of the fruit and allowed the efficient use of water. (Steinmetz, Wollmann, Schaefer, Buchmann, David, Tröger, Muñoz, Frör & Schaumann 2016.)

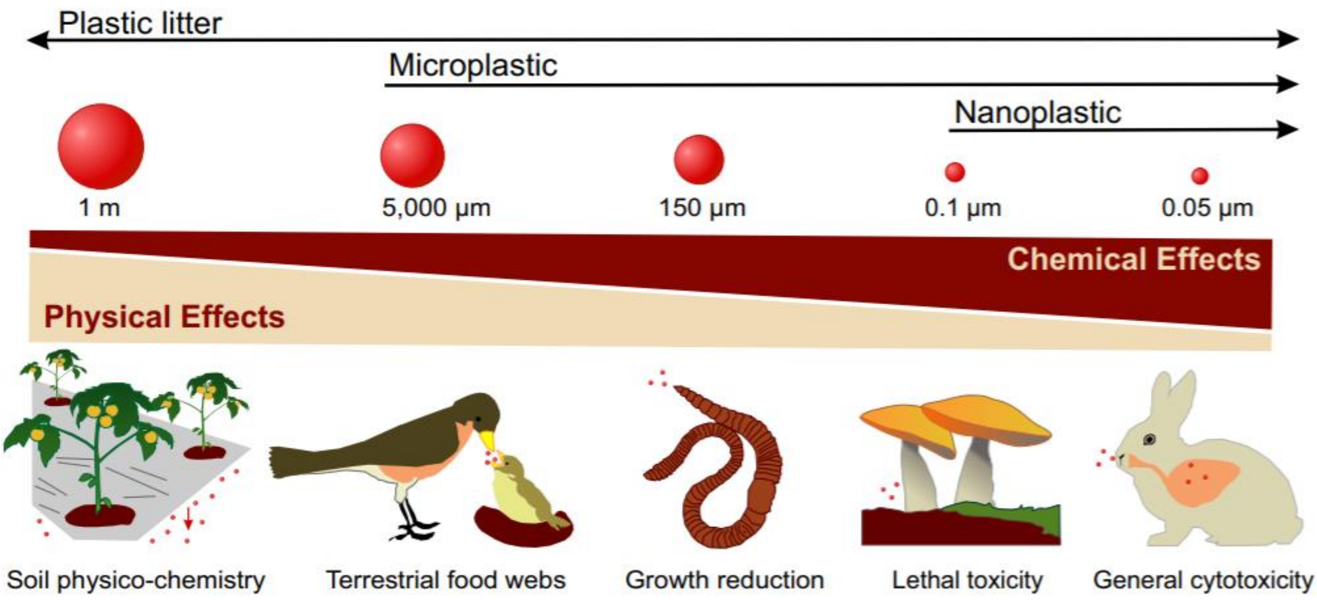

FIGURE 2. Microplastics as trigger of combined physical or chemical-like effects (Machado, Anderson Abel de Souza, Kloas, Zarfl, Hempel & Rillig 2018)

However, plastic additives and fragmented microplastics can accumulate on the soil and promote soil degradation and water resistance in the long term (Steinmetz et al.2016) . When the size of the plastic is reduced to form microplastics, it can be absorbed, ingested or inhaled through the skin, gastrointestinal track, or lung. These microplastics can physically block the digestive organs, irritate and wear down the mucous membranes. When the size of the microplastics is reduced to less than 1 µm so that the nanoplastics are formed, they pass through the primary tissue barrier in vivo and enter the capillary blood vessel through the blood stream. It can penetrate and dissipate throughout the body. (Lehner, Weder, Petri-Fink & Rothen-Rutishauser 2019a.)

Microplastics have a hydrophobic property that is insoluble in water and can be dispersed, but various properties appear. Representative nanoplastics of 1 nm to 1 µm have been reported to exhibit colloidal behavior. These nanoplastics can bind to various biomolecules, which means they can bind to biofilms, tissues and organs (Lehner et al. 2019a). Representative PS nanoplastic research shows that nanoplastics have intestinal binding ability through binding to intestinal cells, and depending on the surrounding biological environment, cellular uptake and toxicity due to binding to protein corona has been reported to increase (Hesler, Aengenheister, Ellinger, Drexel, Straskraba, Jost, Wagner, Meier, von Briesen, Büchel, Wick, Buerki-Thurnherr & Kohl 2019; Forte, Iachetta, Tussellino, Carotenuto, Prisco, De Falco, Laforgia & Valiante 2016).

In addition, these nanoplastics can pass through the primary tissue barrier and pass through the bloodstream to a variety of organs, which has also been shown to increase the permeability called the blood-brain barrier (BBB) (Yang, C., Chang, Tsai, Chen, Tseng & Lo 2004). Apart from size, functional groups are also significantly affected. In positively charged nanoplastics, negatively charged molecules on the cell surface result in nonspecific binding, which significantly increases cell uptake and toxicity. (Tautzenberger, Kovtun & Ignatius 2012.) It can also lead to oxidative stress / damage and can cause endocrine disruption or acute toxicity (Lehner, Weder, Petri-Fink & Rothen-Rutishauser 2019a).

When microplastics are exposed to ecosystems, other chemicals, such as unreacted monomers or by-products, plasticizers, additives, pigments, stabilizers and solvents, can be leached during the manufacturing and processing of plastics (Alimi, Farner Budarz, Hernandez & Tufenkji 2018). Representatives such as styrene monomer of PS, plasticizer for polyvinyl chloride (PVC) production, and bisphenol A added to polycarbonate production have been reported to be associated with cancer and reproductive problems (vom Saal & Hughes 2005). Microplastics also contain persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and organochlorine pesticides (OPs) from the environment (Doorn 2017).

This is due to the fact that microplastics have a large specific surface area, hydrophobic properties, and surface modification due to environmental factors (Teuten, Rowland, Galloway & Thompson 2007 Teuten, Saquing, Knappe, Barlaz, Jonsson, Björn, Rowland, Thompson, Galloway, Yamashita, Ochi, Watanuki, Moore, Viet, Tana, Prudente, Boonyatumanond, Zakaria, Akkhavong, Ogata, Hirai, Iwasa, Mizukawa, Hagino, Imamura, Saha & Takada 2009; Engler 2012). Furthermore, various residual organic pollutants were adsorbed onto PVC and PE, and desorbed under seawater and physiological conditions, and it was confirmed that they were desorbed more than 30 times under physiological conditions (Bakir, Rowland & Thompson 2014). Therefore, microplastics can release toxic monomers or additives, and can adsorb contaminants and deliver them to other places, thus acting as a reservoir or carrier and transporter of substances that can harm the ecosystem.

2.2.2 Effect of Microplastics on Marine ecosystem

After Dr. Carpenter (1972) and Dr. Thomson (2004) reported to the journal Science that microplastics increase in the marine environment, research on the status and ecosystem impacts of microplastics in the marine environment has increased rapidly (Carpenter & Smith 1972; Thompson, Olsen, Mitchell, Davis, Rowland, John, McGonigle & Russell 2004). Approximately 90 % of all plastic waste getting into the ocean all around the world is flushed through rivers, littering, windblown, industrial and municipal waste (Murat Suner 2020). Enormous amounts of plastic have been disposed of as waste in the oceans in every year, which have resulted in the formation of microplastics sculpted by physicochemical forces such as photolysis, oxidation, hydrolysis and physical decomposition. Accordingly, research on the effects of microplastics on various marine organisms such as zooplankton, bivalves, mussels, shrimps and fish is being actively conducted. (Cole, Lindeque, Fileman, Halsband, Goodhead, Moger & Galloway 2013; Li, Yang, Li, Jabeen & Shi 2015.)

According to a study in which the zooplankton was ingested with PS microplastics of 7.3 to 30.6 µm, the smaller the size of the microplastic, the higher the microplastic uptake of the zooplankton, and the reduced function and intake capacity. It has been shown to deliver pollutants and to excrete feces containing microplastics (Cole, Lindeque, Fileman, Halsband, Goodhead, Moger & Galloway 2013). According to a study in which PS microplastics of various sizes were fed to monogonont rotifers, microplastics were expressed in the oxidative stress and antioxidant expression of the monosodium rotifers, P38 and JNK MAPKs proteins has been reported to decrease the growth rate, productivity, lifespan, reproduction time and body size (Vianello, Boldrin, Guerriero, Moschino, Rella, Sturaro & Da Ros 2013). In particular, microplastics of less than 1 micro may be combined with other substances to produce acute toxicity (Cole, Lindeque, Fileman, Halsband, Goodhead, Moger & Galloway 2013). In addition, mussels were exposed to 80 µm high-density polyethylene (HDPE) under various conditions from

3 to 96 hours. It has been reported to significantly reduce the stability of lysosomal membranes (von Moos, Burkhardt-Holm & Köhler 2012 Egbeocha, Malek, Emenike & Milow 2018).

2.2.3 Risks on Microplastics Exposure and Limitations of Toxic Studies

Since the ocean has a variety of marine resources such as biological, mineral and energy resources, it is an important area for nourishment or value creation. As microplastics affect the marine environment, humans using plastics are also at risk of microplastics. Recently, research on the risk of human exposure to microplastics due to ingestion of marine organisms has received attention (Seltenrich 2015 Bouwmeester, Hollman & Peters 2015), and microplastics have been found in mussels and fish, which are popular seafood products (Li, Yang, Li, Jabeen & Shi 2015 Gall & Thompson 2015). As shown in FIGURE 3, it has been reported that plastic such as polyethylene terephthalate (PET), polyester (PES), PE, poly-1-butene (PB), and polypropylene (PP) and cellophane (CP) have been found from salts purchased in supermarkets(Yang, D., Shi, Li, Li, Jabeen & Kolandhasamy 2015a).

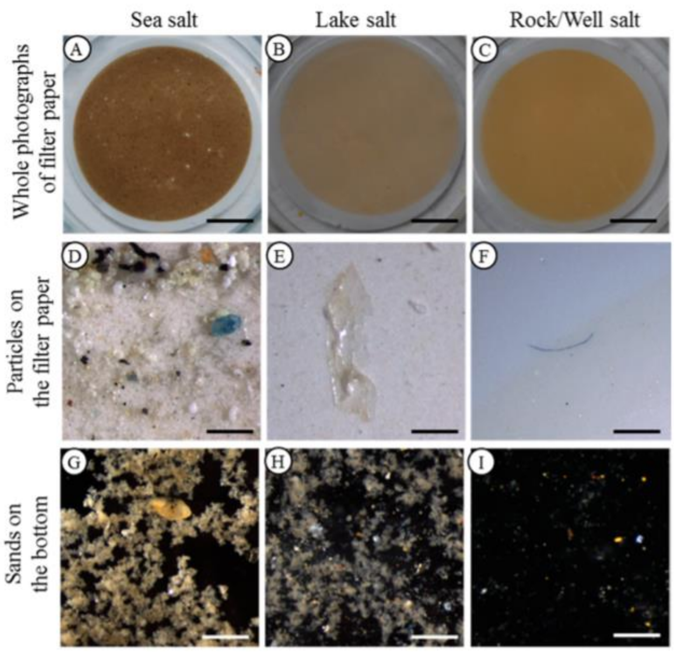

FIGURE 3. Photographs of the total particles isolated from table salts. A−C, the particles in the salt solution without separation; D−F, the particles in the supernatant of the salt solutions. More particles were observed in sea salts (D) than lake salts (Yang, D., Shi, Li, Li, Jabeen & Kolandhasamy 2015b).

Lehner, Weder, Petri-Fink & Rothen-Rutishauser (2019b) analyzes the potential risks of microplastics to humans, the analysis of PS based microplastics on various human cells has shown that they have a major impact on the immune system. In most studies; however, the risk of microplastics in humans is based on the analysis of the effects of microplastics on marine organisms or on the treatment of human cells with PS or other nanoplastics. In other words, there is a lack of evidence that humans can absorb microplastics or demonstrate biological effects through the intake of marine foods or other routes. Therefore, the research on the effects of microplastics on the human body is necessary desperately. (Lehner, Weder, Petri-Fink & Rothen-Rutishauser 2019b.)

3 MICROPLASTICS DETECTION METHODS

In order to more systematically understand the impact of microplastics on the ecosystem, scientific methods are needed to quantify and differentiate microplastics. Microplastics are heterogeneously mixed in size, shape, color, specific gravity, and chemical components and require analysis techniques to separate and distinguish plastic components. (Ryan, Moore, van Franeker & Moloney 2009.)

Monitoring microplastics in various bio-environments can provide basic scientific information to determine the level of contamination, gradients of contamination, and the degree of exposure of organisms to plastics. In microbiological testing or sampling of the environment, the analysis process for microplastics consists of extraction, separation, identification, quantification, and classification. It is very difficult to distinguish microplastics using one analysis method because microplastics are composed of various sizes, shapes, and polymer types. Thus, it analyzes microplastics by mixing two or more types of analytical techniques. In general, microplastic analysis uses a microscopy method to observe the structural, physical, and morphologic properties of a surface and uses a spectroscopy method to observe the chemical components of the microplastic. (Shim, Hong & Eo 2017.)

3.1 Microscopy methods

Structural properties and morphology studies of microplastics have been analyzed using optical microscopes based on color, size, and shape. Microscopy is used to analyze microplastics of various sizes ranging from hundreds of microns to tens of nanometers in size. Scanning electron microscopy (SEM) can provide very sharp and high magnification images of materials such as plastics. It is very useful for distinguishing microplastics from common organic matter through high-resolution images of particle surfaces. By using energy-dispersive X-ray spectroscopy (EDS) together, the elemental composition of the same material can be determined (Cooper & Corcoran 2010).

As a result of analyzing the sediment samples collected from the North Sea Island, PE, PP, PS, polyamide, chlorinated PE, and chlorosulphonated PE were found in all samples. In the case of general microplastics, organic additives are mixed together to increase mechanical and thermal properties, and recently, inorganic additives are also added to the process to improve flame retardancy, antioxidant, processability, and optical properties. In addition to distinguishing polymers in waste plastics, pyrolysis-gas chromatography mass spectrometry (Pys-GC/MS) is used in the microscope to identify organic / inorganic additives, increasing the accuracy of component analysis. Through Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), it is possible to measure the content of the fine plastic particles together with the shape and inorganic type. In addition to the organic compounds (diethyl phthalate, benzaldehyde, 2,4-di-tert-butylphenol) contained in the microplastics using the Pys-GC/MS method, inorganic (TiO_2) nanoparticles were analyzed. (Fries, Dekiff, Willmeyer, Nuelle, Ebert & Remy 2013.)

Recently, a hyperspectral imaging system (HIS) has been used as a new optical microscope method for separation and analysis of microplastics. The HIS method has a narrow spectrum composed of tens to hundreds of spatial pixels from visible light to infrared light. As a result, it is very effective in analyzing chemical components of individual spatial pixels according to spectral information. (Serranti, Palmieri, Bonifazi & Cózar 2018 Shan, Zhao, Liu, Zhang, Wang & Wu 2018.)

3.2 Spectroscopy methods

Quantitative analysis of chemical properties and composition of microplastics has been studied using spectroscopy. The Fourier transform infrared (FT-IR) method is capable of qualitative and quantitative analysis of chemical bonding of substances by measuring the absorbance according to the wavelength by irradiating infrared rays to the sample, and the location and intensity of the absorption band. Carbon-based polymers can be easily analyzed by FT-IR and are useful for identifying organic and inorganic materials from plastics because the corresponding spectra is generated according to the composition of the bond (Löder & Gerdts 2015). When the attenuated total reflection (ATR) mode is used, a stable absorption wavelength region can be obtained even in microplastics with irregular surfaces, unlike the reflection mode (Engler 2012).

In addition, micro FT-IR is used to identify and distinguish irregularly shaped microplastics by directly implementing images. Optical microscopes have the advantage of being able to distinguish microplastics faster and easier than FT-IR. However, when using an optical microscope, it is difficult to accurately distinguish non-plastics from plastics when the sample size is 1 mm or less, so it is possible to misinterpret the concentration and type of microplastics. Spectroscopy using FT-IR enables accurate measurement of microplastics as small as 50 micromillimeters or less, enabling analysis of the type and concentration of polymers contained in plastics (Song, Hong, Jang, Han, Rani, Lee & Shim 2015). Fourier transform micro-infrared spectroscopy (μFT-IR) and environmental scanning electron microscopy-EDS (ESEM-EDS) enable the chemical mapping of microplastic surfaces, resulting in particle composition (main atomic composition of polymer) and morphology (Engler 2012).

3.3 Thermal analysis

Thermal analysis is used to distinguish microplastics by measuring changes in the physical and chemical properties of a polymer according to the thermal stability of a material. Differential scanning calorimeter (DSC) measures the difference in heat flow from a sample by applying the same temperature program to a sample and an inert reference in a furnace to measure the amount of energy. Qualitative characteristics of the sample can be confirmed through information proceeding. Thermogravimetric analysis (TGA) measures the change in mass of a sample as a function of time or temperature by applying a temperature program to the sample. Majewsky researchers used TGA-DSC to analyze the mass and concentration of polymers by distinguishing seven different plastics from microplastic samples taken from the ocean (Majewsky, Bitter, Eiche & Horn 2016).

TGA is used in conjunction with thermal desorption gas chromatography mass spectrometry (TDS-GC-MS) to provide very useful information for the detection of PE in microplastics. Py-GC-MS measures the mass of a sample that is approximately 200 times higher than TDS-GC-MS of an advantage in that it can accurately measure a large amount of non-uniform microplastic. In addition, since the qualitative and quantitative analysis of the microplastic samples collected in various environments using the TDS-GC-MS method is quick and easy, the PE contained in the sample PE, PP, PS can be separated and screened with precision. (Dümichen, Barthel, Braun, Bannick, Brand, Jekel & Senz 2015.)

4 INTERNATIONAL COUNTER MEASURES AND RESEARCH TRENDS ON MICROPLASTICS

Microplastics are so small that they are almost impossible to recover if they are spilled into nature. Hence, countries around the world are tightening related laws on primary microplastics. EU countries such as the Netherlands, Belgium and Sweden have enacted laws prohibiting the use of fine plastics for cosmetics, detergents and other products. The European Union (EU) is working to maintain a "clean, ocean free of debris" by establishing a marine debris regulation called MSRL. The policy includes measures to reduce the production of synthetic resins and plastics that harm the marine environment, starting with minimizing the release of microplastics and gradually limiting the production of primary microplastics. In addition, the EU is taking measures to develop plastic recycling technologies, biodegradable plastics, to identify hazardous materials in plastics, and to prevent marine debris from developing in a circular economy package (European Commission Act 15.112018).

Italy announced seven initiatives on marine debris in its 2017 Bologna statement (European Commission Act 12.62017). Based on the G7 Action Plan (G7APML), the statement recognizes the environmental, social and economic impacts of microplastics and identifies ways to prevent and reduce the generation of marine debris through efficient resource utilization and sustainable material and waste management. Japan also declared with G7 and Action Plan in 2016 to recognize and address the threat of microplastics to marine ecosystems in its Toyama statement (European Commission Act 12.62017). Based on this, priority measures such as suppressing and reducing the generation of marine debris, sound waste management and financing for wastewater treatment were discussed.

As the international community becomes more aware of the threat of microplastics, the development of eco-friendly plastics (biodegradable plastics defined as 100 % naturally decomposed when buried in soil) used in waste plastic recycling technology and bioplastics between environmental groups and countries. Germany, where waste plastic recycling technology is the most advanced, focuses on fueling waste plastics. For the recycling of energy, solid raw materials are used as fuel to recover heat or to generate electricity. On the other hand, in Japan, recovery of waste plastics is the main waste plastic recycling policy. Recycling of materials includes the process of washing and pulverizing waste plastics and turning them into reusable plastics to produce other products. Through this, according to a report in 2008, Japan recycled 660,000 tons of plastic, which is 13 % of the 5 million tons of household waste plastics. In the case of Korea, it is pursuing a waste plastic policy that prioritizes material recycling and considers energy utilization. (Korea Institute of Industrial Technology Evaluation and Management 2019.)

Research on bioplastics that replace petroleum-based plastics and fewer environmental burden from landfilling has been in the spotlight. Harvard University's Wyss Institute has succeeded in developing biodegradable plastics from shrimp shell chitin. The produced plastics have the same strength as the conventional plastics but show a property of degrading naturally when exposed to moisture. The Newlight Technologies company in the United States has developed a way to make plastics from carbon dioxide from industries such as wastewater treatment plants, landfills, and power plants. Since it does not manufacture plastics using oil, it has the advantage of reducing greenhouse gas emissions by recycling carbon dioxide in addition to reducing the use of crude oil. (Joo, Cho, Seo, Son, Sagong, Shin, Choi, Lee & Kim 2018.)

5 REGULATION OF MICROPLASTICS IN THE WORLDS

Microplastics continue to threaten marine and coastal habitats, such as altering or decaying marine habitats through sun protection and surface damage. Environmental issues of plastics, which contributed to the convenient life of mankind, such as microplastics are detected throughout commercially available bottled water and beverages, are emerging as a global issue. Accordingly, legislation and regulations are in place around the world for the regulation of microplastics.

5.1 United states

Illinois banned the use of microplastics for the first time (July 2014), and although states have different biodegradability and product ranges, several states have or are in the process of regulating microplastics as shown in TABLE 2. This has resulted in a ban on personal hygiene products. (US Federal Law for Microbead-Free Waters 2015.)

TABLE 2. Microplastic Regulation in US (US federal law Act 4.32018)

Period	Content
After 1st, July, 2017	Prohibit production of cleaning cosmetics containing microbeads
After 1st, July, 2018	-Prohibit commercial transactions of cleaning cosmetics containing microbeads -Prohibit the production of cleaning products classified as drugs that can be purchased without prescription
After 1st, July, 2019	Prohibit commercial transaction of over-the-counter cleaning products containing microbeads

5.2 France

For the first time to publish statement for the biodiversity to restore nature and landscape, (Le project de loi pour la reconquete de la biodiversite, de la nature et des paysages), prohibits the sales of cosmetic products containing microplastics, disposable tableware, plastic cotton swabs and pesticides containing neonicotinoids will be banned by 2020. (Nationale 2018.)

Moreover, the first country that the European Union member states adopted the ban was France, which banned the sale of rinsing cosmetic products for exfoliation or cleaning with solid plastic particles. The French ban does not specify the size of plastic particles, so all solid plastic particles are banned and particles larger than 5mm are also banned. Cosmetic companies such as Unilever and L'Oreal, representing France, are gradually reducing production of related products and developing alternative products. (Kentin & Kaarto 2018.)

5.3 Canada

Canada have announced plans to prohibit the use of microplastics in personal hygiene products (Microbead Monitoring and Elimination Act 9.32015) and are currently in the process of introducing legal regulations throughout Canada, including the Toxic Substances List like TABLE 3. In addition, as of June 2019, the Vancouver City Council has passed a law banning the use of disposable plastic products in all restaurants (Prohibition of Certain Toxic Substances Regulations, 2012).

TABLE 3. Regulation microplastics in Canada (Prohibition of Certain Toxic Substances Regulations, 2012)

Period	Content
Until 31st, December, 2017	Prohibit manufacture and import of personal hygiene products containing microbeads, including peeling and cosmetics *Excluding general medicine and natural health functional food
Until 31st, December, 2018	Prohibit the sale and distribution of personal hygiene products containing microbeads, including peeling and cosmetics *Excluding general medicine and natural health function food
	Prohibit the manufacture and import of general health functional foods used for general medicines containing microbeads, peelings and face washing
Until 31st, December, 2019	Prohibit the sale and distribution of general medicines containing microbeads and natural health functional foods used for peelings and face washing

5.4 United Kingdom

Following the ban on microplastics in January 2018, the UK also banned the sale of cosmetics and personal care products containing microplastics in June 2018. The UK government's fine plastics regulations were implemented to continue efforts and support to increase the recycling rate of resources as part of the 25-year Environment Plan, announced by Prime Minister Teresa May in January 2018. It aims to eliminate completely unnecessary plastic waste by year (Carrington 2018). Moreover, a deposit refund system for plastic bottles was introduced (2018.3) and the sale of cotton swabs using plastic and plastic bags was also banned (April 2018). In addition, large markets such as Tesco and Asda, and food and beverage companies such as Nestle and Coca Cola are actively participating in the change of disposable plastic packaging systems and participation in plastic agreements organized by charities to preserve the marine environment. (Kathryn manktelow 2019.)

5.5 The other Countries

The EU has announced that by 2021, it will expel disposable products such as plastic straws and plastic bowls. In addition, legislation has been proposed to expand the supply of reliable drinking water to reduce the use of plastic bottles for drinking, and member countries have installed water systems in public buildings, places where are easily accessible to all citizens, including vulnerable and marginalized groups. The EU member states decided to provide online information on where drinking water can be found anywhere and wherever the quality is(UKgovernment 2018). In addition, New Zealand plans to ban the use of disposable plastic bags from 2019 (New Zealand Ministry for the Environment Act 1.72019), and India has decided to withdraw all disposable plastic bags by 2022 (Anisha Bhatia 2017). Kenya has the strictest plastics regulations in the world. If they are caught using plastic bags, they will be fined $ 39000 or imprisoned for less than four years (Deutsche Welle 2018).

6 DISCUSSION

Despite the risks of microplastics, a survey conducted by Greenpeace (June 2016) found that 86 % of respondents said they lacked self-regulation by the government. It is necessary to establish a virtuous cycle of sustainable eco-friendly production and resource recycling, such as encouraging the expansion of environmental risk research and mandating the use of alternative products that do not contain hazardous substances.

6.1 Establish risk management Standards

Microplastics are characteristics that attract other chemicals, such as absorbing or adsorbing dissolved pollutants in rivers or seawater. Once plastic is released into the environment, it is necessary to designate hazardous substances. It is necessary to assess the degree of microplastic pollution in major waters of each country, to analyze major sources of inflow, to identify diffusion and migration routes, to accumulate organisms and to evaluate toxicity, and to establish management standards for reducing marine environmental risks.

6.2 Expand Plastic Recycling Policy and Enhance legal regulations

According to a 2016 report by the Ellen MacArthur Foundation and McKinsey & Company, plastic packaging is only 14 % recycled worldwide. Incineration (14 %), landfill (40 %) and the rest of the waste are shown to be introduced into the ocean (32 %). As such, the plastic recycling rate is very small. To reduce the contamination of microplastics, it is necessary to reduce the use of excessive plastic packaging materials or disposable plastic containers, and to increase the recycling of plastics that have already been produced. Also, in order to increase the recycling rate of plastic containers, bottled water and beverages should be manufactured only with colorless plastic bottles, and those with different colors or materials should be excluded. In other words, to improve plastic recycling, standards for materials should be created and managed from the production stage. Particularly urgent for recycling is plastics for fishing. More than 70 % of marine waste is generated from fishing activities. To reduce this, it is most necessary to collect and recycle plastic waste from fishing.

Microplastics require proper regulation by accurately identifying emission sources and serious situations where are released by washing, tires and so on. Currently, microplastic regulation policies and research are limited to marine and household products. Therefore, it is necessary to manage the fishing gears and buoys used by fishermen and it is urgent to strengthen legal regulations on various microplastic pollutants such as prohibiting the use of all kinds of solid microplastics.

6.3 Active participation in reducing disposable products

Plastic marine debris is damaging to life, tourism and fisheries. The problem is serious because microplastics are distributed globally and not only have toxic effects, but also spread through the food chain. As such, the discarded plastic is brought back to kitchen table, and government-wide efforts are needed to reduce the plastic. The most urgent task is for governments, businesses and citizens to ban plastics quickly and maximize plastic recycling. From now on, the government should move towards prevention-oriented policies that reduce the inflow of marine waste. In addition to reducing the amount of waste so that the amount of waste does not increase any more, it is also necessary for the public to recognize the problems caused by marine plastic waste, to participate in efforts to reduce plastic waste, and to promote and promote education. Therefore, the public should join the movement to reduce plastic by using media such as public campaigns and public service advertisements and practicing public participation, and at the same time expand education for the environment customized for youth and residents. Particularly, improving the education and awareness of fishermen is of paramount importance.

6.4 Realising corporate social respsonsibility

As the concern about environmental pollution caused by plastics is increasing, it is a mood to lead the reduction of plastics by global companies. Unilever, a leading global consumer goods company, has decided to launch a non-profit organization that will drive plastic waste reduction, and Sweden's Volvo Motors has set a target of 25 % recycling of plastics in cars by 2025. In addition, a growing number of sports and apparel companies use recycled PES. If these companies take the lead in fulfilling their social responsibilities in the field of environmental protection, they will be able to attract consumer attention.

6.5 International Cooperation Response

The international community recognizes marine plastic waste as an important environmental issue. The United Nations Conference on Environment adopted a resolution on marine plastic waste and microplastics in 2014 and 2016, and the UN Environment Program calls for action to prevent and mitigate all kinds of marine waste by 2025. The Working Group was set up in 2018 by U.N Environment Program to prepare measures, and the feasibility and effectiveness of the marine waste, obstacles to microplastics response, countermeasures and costs to be addressed nationally, regionally and internationally to resolve marine waste will be discussed.

In addition, since waste introduced into the ocean float across the world across borders, it is necessary to make efforts to cope with international cooperation. The article, published in the journal Science, identifies Asia as the region with the largest inflow of plastic waste in the world (Jambeck, Geyer, Wilcox, Siegler, Perryman, Andrady, Narayan & Law 2015). Therefore, Asian countries should actively participate in and support the establishment of an international network for dealing with marine debris and operating international cooperation programs and take a leading role in protecting the marine environment in the international community.

7 CONCLUSIONS

Since the development of synthetic resins in the late twentieth century, plastic production has soared worldwide. Compared to metal and ceramic materials, plastics provide numerous of convenience to human life because of their excellent durability and structural characteristics, but they have many side effects. Every year, thousands of microplastics are filtered off into the ocean without special technology or equipment. This not only destroys marine ecosystems, but also ecologically returns to humans through the food chain. Research and development are needed to thoroughly identify and analyze the potential impact of microplastics on the environment, the distribution of waste plastics and chemical composition in the ocean.

Many countries are aware of the dangers of microplastics and have started to create relevant laws, administration and regulations. However, management is still necessary compared to microplastic emissions worldwide. Therefore, few discussions are recommended for resolving the problem of microplastics waste. First, it is to establish risk management standards for microplastics. For the marine environment, microplastics are regarded as contaminants, and risk management standards are established through evaluating discharge routes, diffusion, and accumulation in organisms. Second, it is to expand the recycling policy of plastics. Through the policy of increasing the recycling rate of plastics, it is necessary to manage from the production stage to the recovery stage and strengthen legal regulations accordingly.

Furthermore, generally, it is necessary to attitude to reduce disposable products and make it a part of daily routine. For instance, when going to shopping, using own's shopping bag should be tried to reduce the use of plastic bag. When going to café, using a personal tumbler instead of using plastic disposable cup. The amount of disposable waste that has been used indiscriminately should be recognised. Companies as well as individuals should take social responsibility and make efforts to recycle plastics, such as making new fibers from waste plastics, or develop biodegradable plastics for the environment. Finally, international cooperation is highly recommended. Since plastics wasted into the sea do not settle in one place and flow into the world through the sea regardless of borders, cooperation with the international community is actively needed and make various efforts, such as establishing a response network.

Recently, eco-friendly materials such as biodegradable plastics have been developed, but their economic effects are insignificant compared to conventional general-purpose plastics. Research into the development of technology to produce plastic using microorganisms or to decompose chemically produced plastics into microorganisms should be intensified. In addition, governments in each country should raise awareness about microplastics and provide policy support to solve marine debris problems by strengthening waste regulations, regulating the use of general-purpose plastics, and promoting waste plastic education.

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